

PHENO 2004

Madison Wisconsin, April 26, 2004

DØ single top searches in the μ +jets channel

Summary

- ◆ Single top production at the Tevatron and properties
- ◆ Search strategy
- ◆ B-tagging:
 - ★ Soft Muon Tagger and Secondary Vertex Tagger
 - ★ Background estimation from MC and from data
- ◆ Systematic errors, events yields and plots of distributions
- ◆ Expected limits for 158 pb^{-1} of collected data

Electroweak production of the top quark

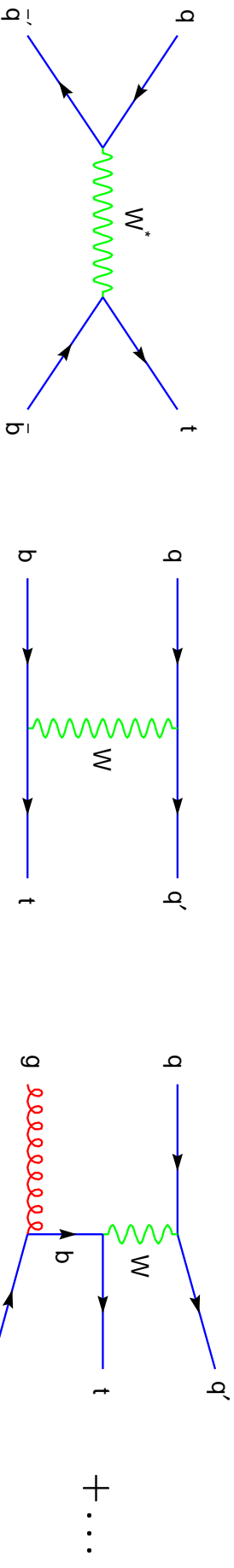
Two completely independent processes through W-exchange:

s-channel: $p\bar{p} \rightarrow t\bar{b} + X$ ($t\bar{b}$, $t\bar{b}$); and t-channel: $p\bar{p} \rightarrow tq\bar{b} + X$ ($tq\bar{b}$, $tq\bar{b}$, tq , tq)

NLO σ for $\sqrt{s} = 1.96$ TeV and $M_t = 175$ GeV/ c^2 (hep-ph/9604223, hep-ph/0207055)

$$\sigma_s = 0.88 \pm 0.07 \text{ pb}$$

$$\sigma_t = 1.98 \pm 0.21 \text{ pb}$$



Total production cross section $\sim 40\%$ of $t\bar{t}$, but...

- Access to Wtb vertex \rightarrow Measure V_{tb} directly, test unitarity of CKM
- Test $V-A$ structure \rightarrow New physics: W' , top pions π^\pm , \tilde{t} , anomalous couplings?
- Study top polarization, mass

Run I 95% CL limits:

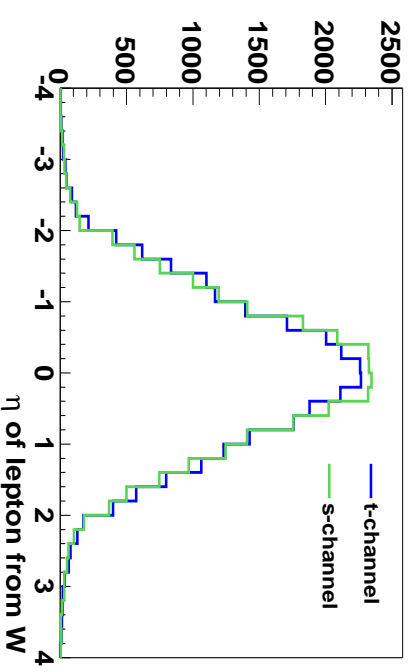
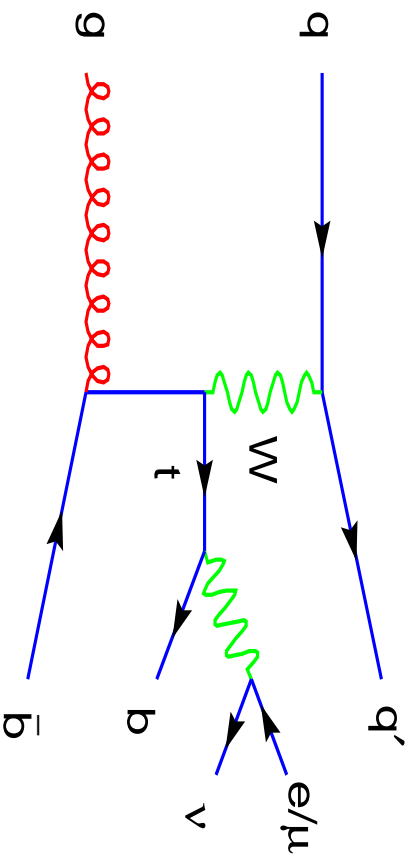
$$\sigma_s < 17 \text{ pb (D}\emptyset\text{)} ; 18 \text{ pb (CDF)} \quad \sigma_t < 22 \text{ pb (D}\emptyset\text{)} ; 13 \text{ pb (CDF)}$$

With increased \mathcal{L} , increased production cross section (+30%), and b -tagging



Flagship discovery in Run II

Signal topology

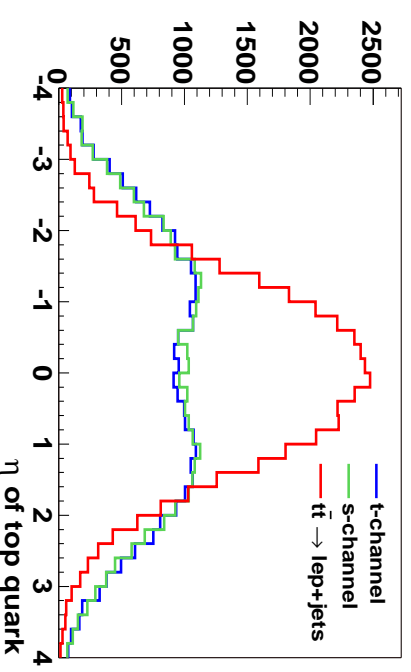
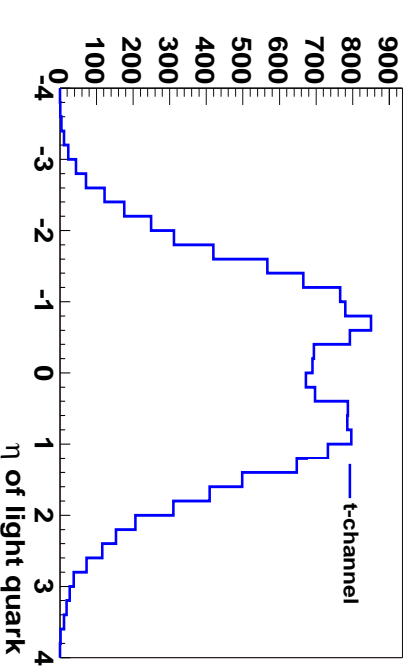
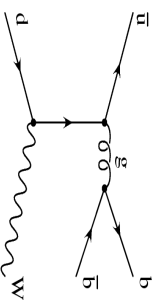


The signature we are looking for:

- One high- p_T isolated lepton (from W)
- E_T (ν from W)
- One b -quark jet (from top)
- A light flavor jet and/or another b -jet

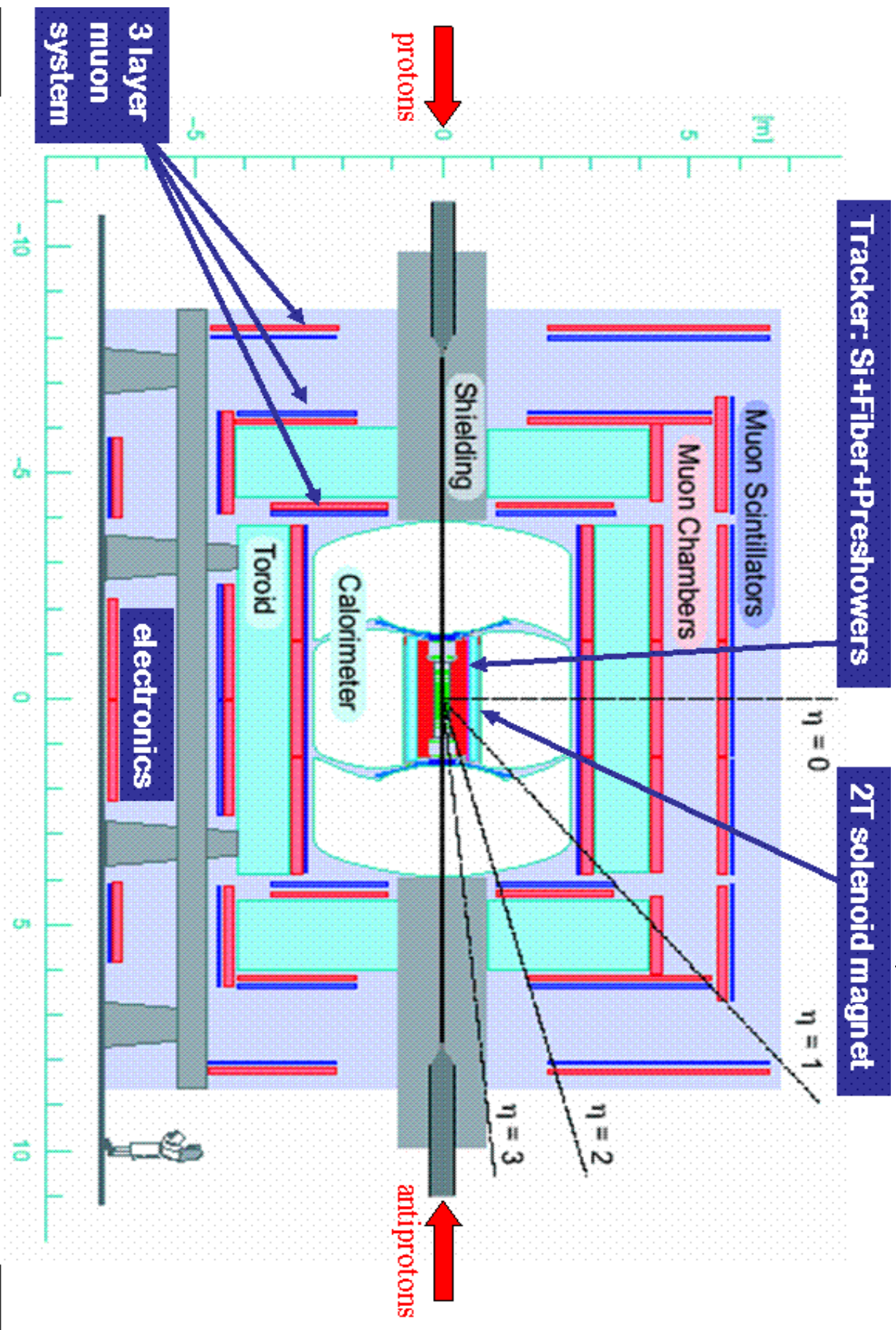
Main backgrounds:

- W +jets (from data)
- $t\bar{t} \rightarrow \ell$ +jets and $t\bar{t} \rightarrow \ell\ell$
- misreconstructed multi-jets events
- $Z \rightarrow \mu\mu$ only for soft-muon tag analysis



The Run II DØ detector

So far 320 pb^{-1} of data recorded in Run II @ $\sqrt{s} = 1.96\text{ TeV}$



Search cuts and MC samples

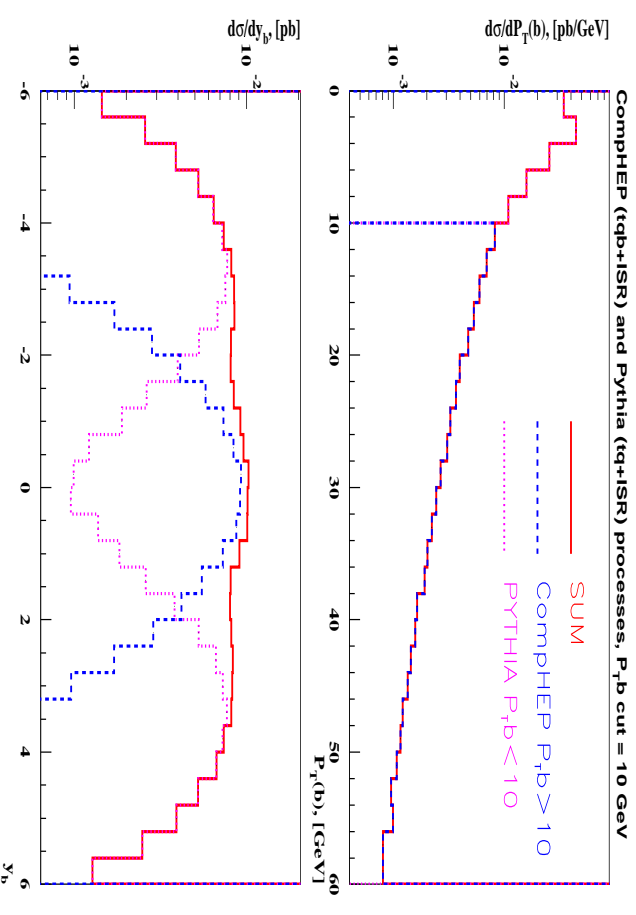
Loose preselection to keep data with similar final state objects to signals

Reject mismeasured events and regions not well described by bkgd. models

- 1 good quality isolated muon: $E_T > 15 \text{ GeV}$, $|\eta| < 2$
- $2 \leq N_{\text{good jets}} \leq 4$
- Leading jet: $E_T > 25 \text{ GeV}$, $|\eta| < 2.5$; Other jets: $E_T > 15 \text{ GeV}$, $|\eta| < 3.4$
- $\cancel{E}_T^{JE^S} > 15 \text{ GeV}$, $\cancel{E}_T > 15 \text{ GeV}$
- $N_{\text{noise jets}} \leq 2$, $\cancel{E}_T < 200 \text{ GeV}$
- Require **at least one b -tag** by **soft- μ tagger** / **secondary vertex tagger**
- Final cut: $H_T = E_T^{\text{jet}^1} + E_T^{\text{jet}^2} + E_T^\mu + \cancel{E}_T > 150 \text{ GeV}$

MC samples (all interfaced to Pythia):

- **SingleTop** for signal:
based on CompHEP, no parton cuts
NLO with full spin correlations
- **Alpgen** for $t\bar{t}$
full spin correlations, no parton cuts
- **Pythia** for $Z \rightarrow \mu\mu$
only for soft-muon tag analysis



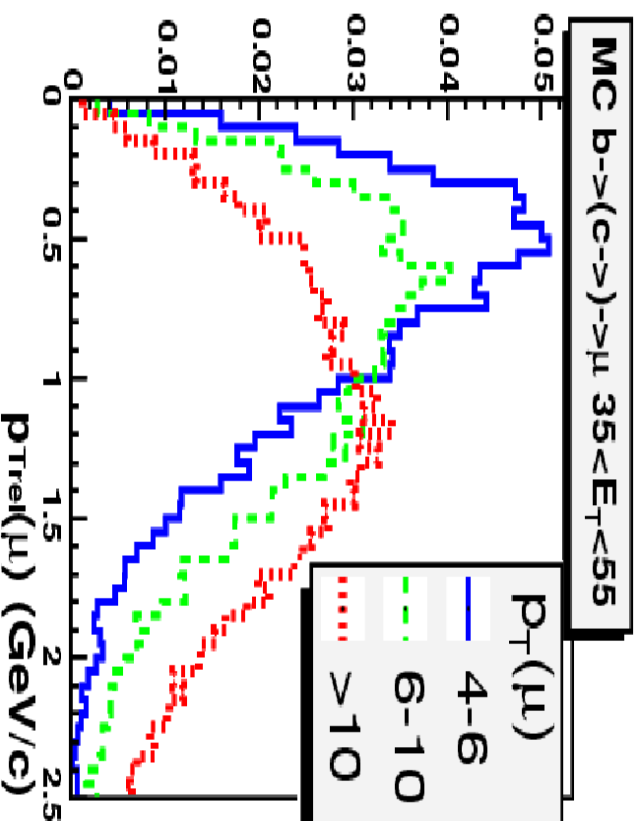
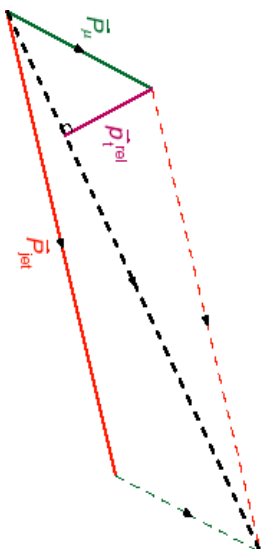
b-tagging methods



Two different *b*-tagging algorithms used independently:

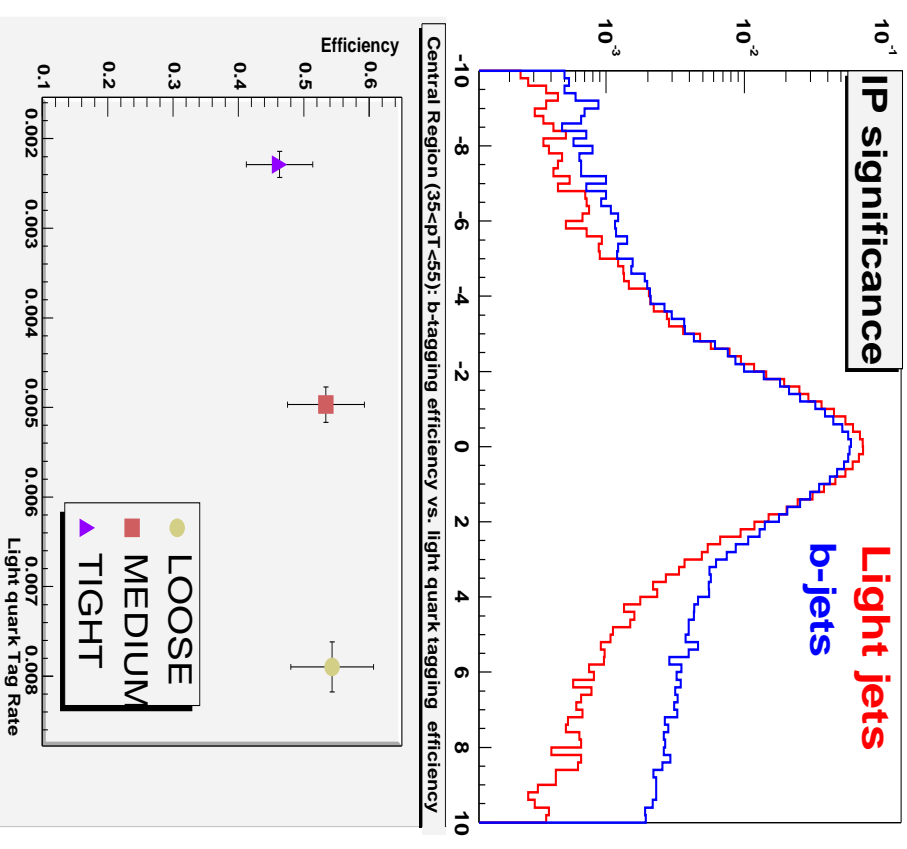
Soft Muon Tagger

- 11% of *b*-jets contain a soft muon
- Look for a muon close to a jet:
 $\Delta R(\mu_{\text{jet}}) \leq 0.5$ and $p_T(\mu) > 4 \text{ GeV}/c$

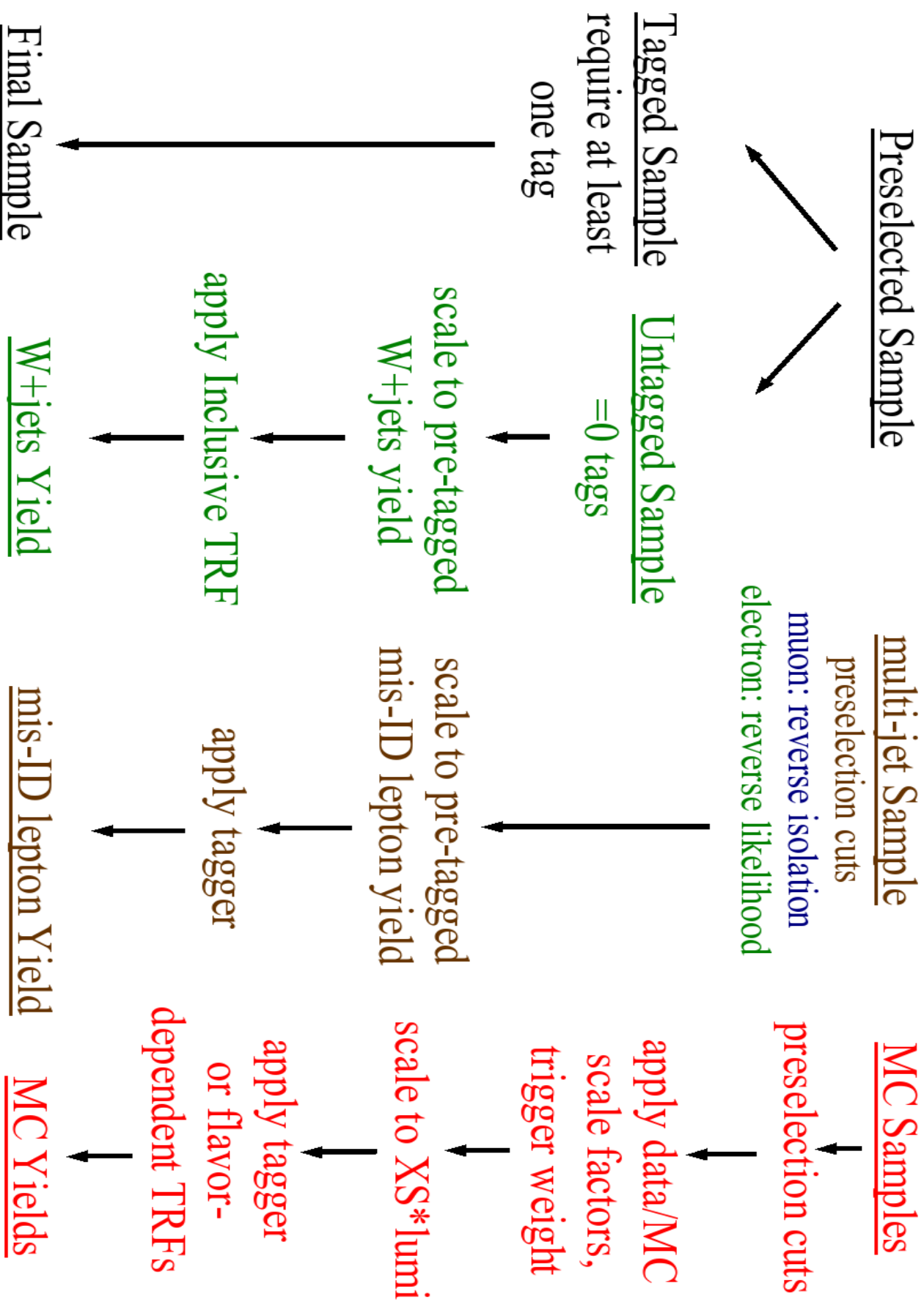


Secondary Vertex Tagger

- Reconstruct a displaced vertex
- Fit tracks with $IP_{\text{trk}}/\sigma_{\text{trk}} > 3.5$
- Secondary vertex if $IP_{\text{vtx}}/\sigma_{\text{vtx}} \geq 7$



Tagged background estimation methods



Tagged MC estimation methods

For signal, $t\bar{t}$ and $Z \rightarrow \mu\mu$ MC samples:

- ★ Correct from **ID efficiencies** (measured in $Z \rightarrow \mu^+ \mu^-$ data and MC):
ID, tracking, matching, isolation **scale factor** = $\epsilon(data)/\epsilon(MC) = 0.86 \pm 0.05$
- ★ Apply **trigger response** and scale to $\sigma\mathcal{L}$
- ★ SVT applies a **flavor dependent tag-rate functions** after parton matching
 - **b-flavor TRF**: $f(E_T, \eta)$ from μ +jets sample with $p_T(\mu) > 8 \text{ GeV}/c$
Count number of muon-jets with vertex, correct with p_T^{rel} templates
 - **c-flavor TRF**: scale b -TRF by c/b -tagging ratio from MC
 - **light-quark TRF**: Use negative side of IP significance



$$\text{Probability}(\text{tag event}) = 1 - \text{Probability}(\text{no jet tag})$$

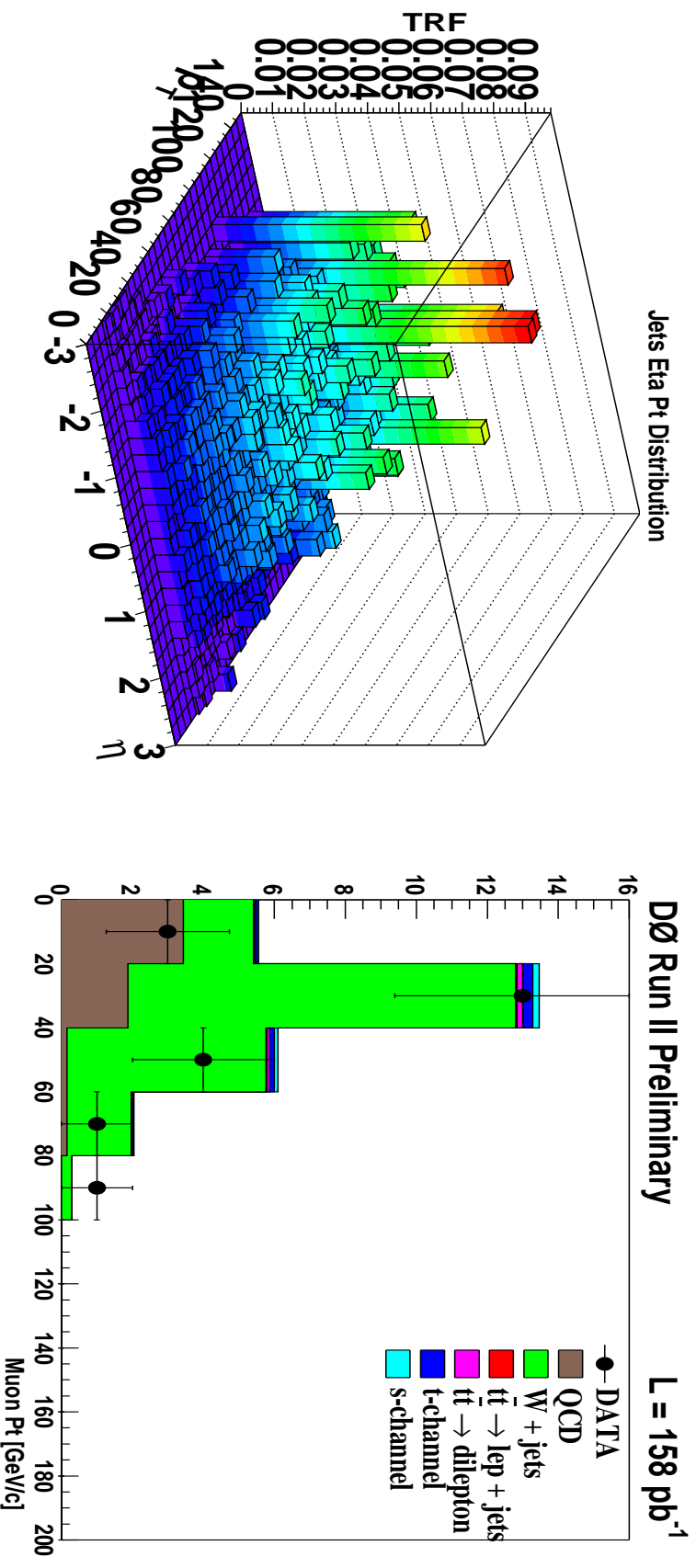
- ★ SLT applies directly the tagger (find soft muon close to jet) on the MC

QCD and W +jets estimation from data

QCD: Generate fake- ℓ sample with reverse isolation cut, scale it to size of pretagged sample and apply the tagger

W +jets: Apply **inclusive tag-rate function** over the preselected sample with 0 tags

- ★ Derive inclusive TRF from multijet sample → Assume that **heavy flavor content** is the same in W +jets and the **multijet** sample for events with same jet multiplicity
- ★ Test assumption with a **clean W +jets sample**: presel + $N_{\text{jets}}=2 + H_T < 200$ GeV
- ★ The tagger applied directly and the TRF agree within errors

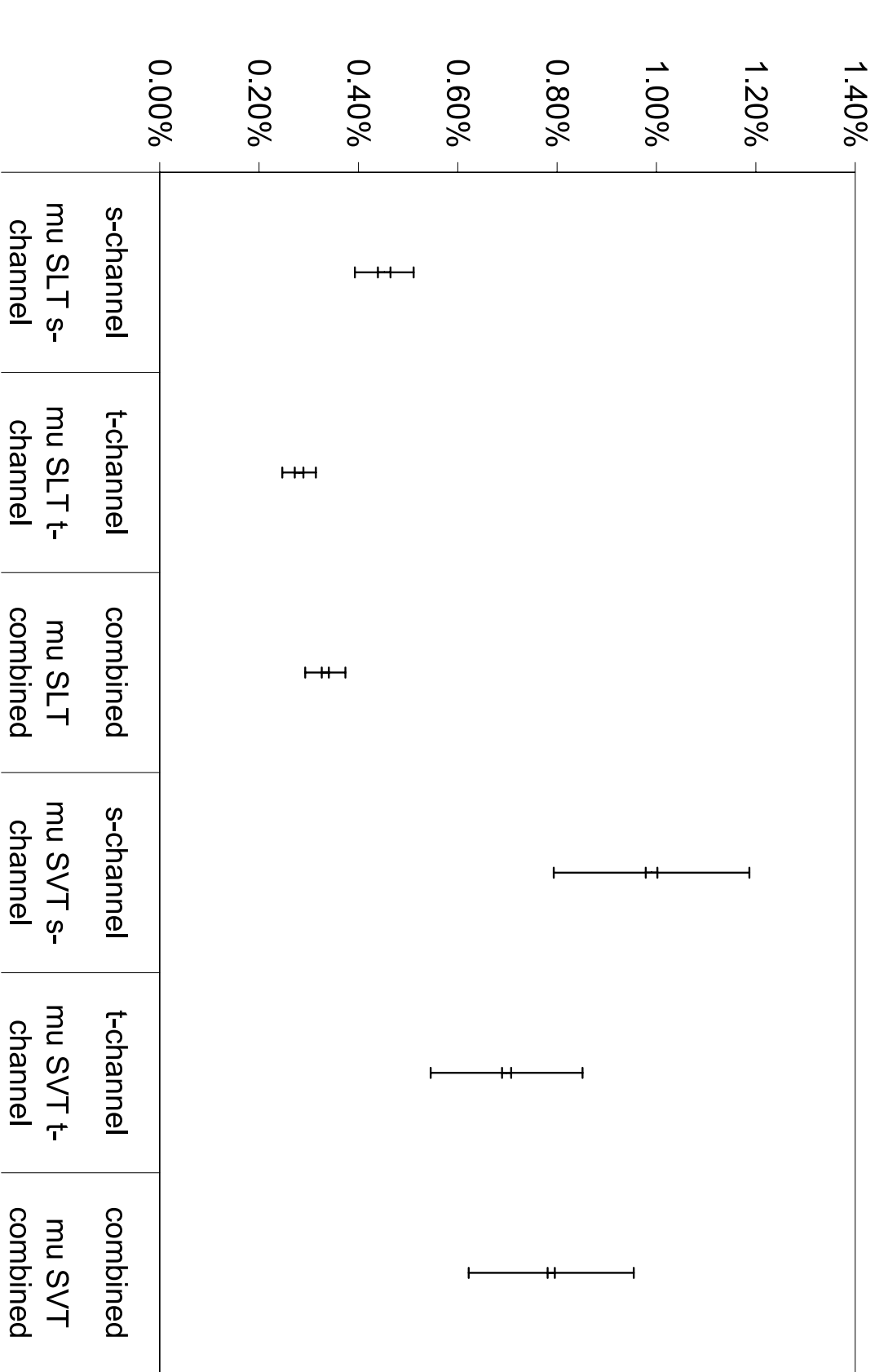


Systematic Uncertainties

MC acceptance uncertainties (%)		Data uncertainties (%)	
jet energy scale	~10	inclusive TRF	20
trigger	~10	$Z \rightarrow \mu\mu$ scale factor	16
flavor dep. TRF	~8	QCD scale factor	13
μ ID	6	W+jets scale factor	3
jet fragmentation	5		
tagging μ model (SLT)	3		
tagging μ veto (SVT)	3		

- ★ Largest uncertainty comes from the heavy flavor composition of the multijet data used to determine the W+jets yield: **inclusive TRF**
- ★ $t\bar{t}$ and single top **production cross sections** are ~15-18%
- ★ **Luminosity** uncertainty is 6.5%
- ★ W+jets and fake- ℓ from QCD uncertainties are **fully anti-correlated**
- ★ Total yield uncertainty for **W+jets and fake- ℓ** is **18%**
- ★ Total yield uncertainty for **MC backgrounds** is **~25%**

MonteCarlo signal acceptance

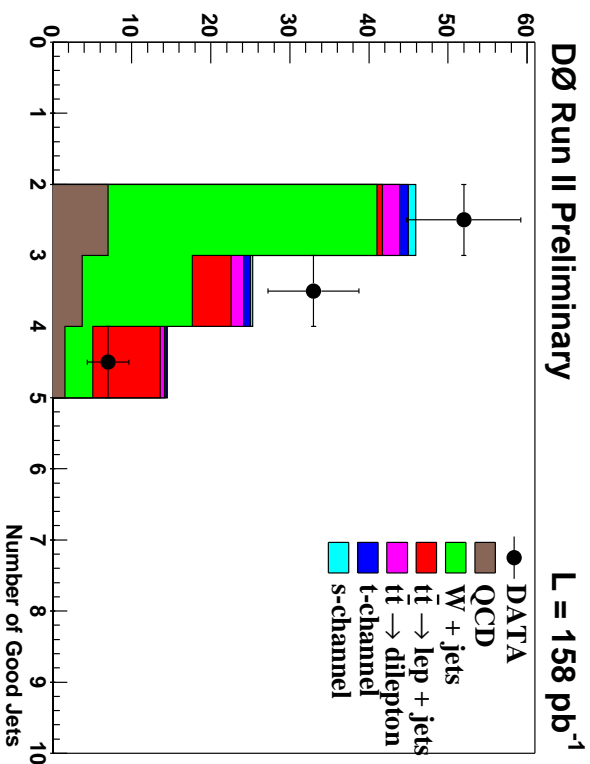


Event yields

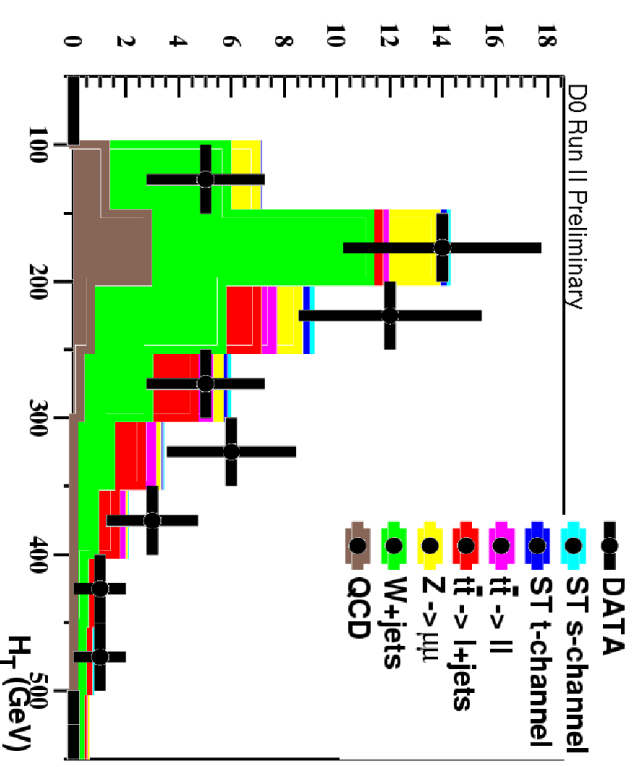
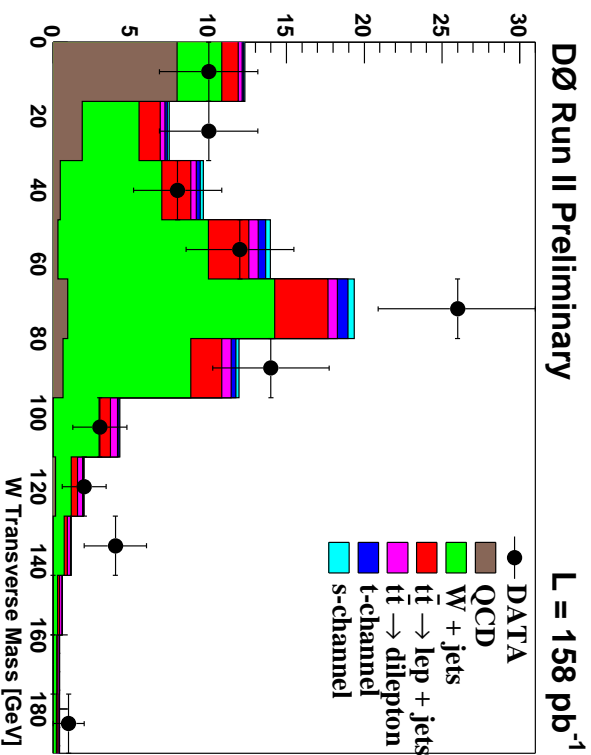
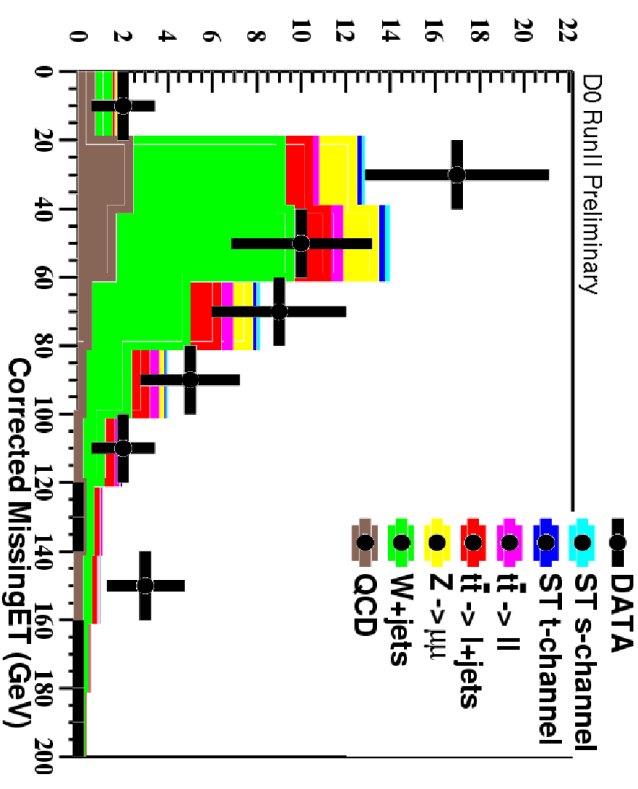
	SLT	SVT
Signals		
MC s -channel	0.6 ± 0.1	1.3 ± 0.3
MC t -channel	0.9 ± 0.3	2.1 ± 0.7
MC $s+t$ combined	1.5 ± 0.4	3.4 ± 1.1
Backgrounds		
MC $t\bar{t} \rightarrow \ell+\text{jets}$	6.2 ± 1.4	14.1 ± 3.4
MC $t\bar{t} \rightarrow \ell\ell$	2.2 ± 0.3	4.2 ± 0.7
MC $Z \rightarrow \mu\mu+\text{jets}$	3.7 ± 0.7	—
$W+\text{jets} + \text{fake-}\ell$ data	23.2 ± 4.0	48.9 ± 8.9
Sum of backgrounds	35 ± 4	67 ± 10
Observed data	43 ± 7	76 ± 9
Acceptance	0.3%	0.7%

Distributions before final cut on $H_T > 150$ GeV

Secondary Vertex Tagger



Soft Muon Tagger



Limit setting: Expected limits

Used **Modified Frequentist approach** (CL_s method) from LEP

- ★ Derive s - and t -channel limits by taking the other's contribution as background
- ★ **Systematic uncertainties are included** as fully correlated or fully uncorrelated
- ★ **Correlations** between channels and background sources are treated properly
e.g. the \mathcal{L} uncertainty is fully correlated between samples (signal, $t\bar{t}$, ...) and analyses (SLT, SVT)
- ★ **SVT and SLT analysis are orthogonal**: SVT requires a veto on a soft-tagging μ
- ★ **Easy combination of taggers and addition of channels**

σ **95% CL Expected Upper Limits With Systematics**

	SLT	SVT	Combined
s-channel	26	20	17
t-channel	40	34	25
$s + t$ combined	32	27	22

Conclusions

With 158 pb^{-1} of data, we see:

Observed Data	Bkg. expected	$s + t$
119 ± 11	102 ± 10	5 ± 1

Muon channel expected limits with systematics taken into account:

$$\sigma_s < 17\text{ pb}$$

$$\sigma_t < 25\text{ pb}$$

$$\sigma_{s+t} < 22\text{ pb} \quad @ \text{ 95\% CL}$$

- Combine limits with the e-channel: see talk by R. Schwienhorst
- Already better results than in Run I ...
- ... and we haven't applied neural networks yet
- ... nor shape fitting to extract better limits
- The Tevatron and $D\bar{D}$ are performing very well
- Many exciting new results to come from this analysis!